EUV Resist Contrast Loss Determination Using Interference Lithography

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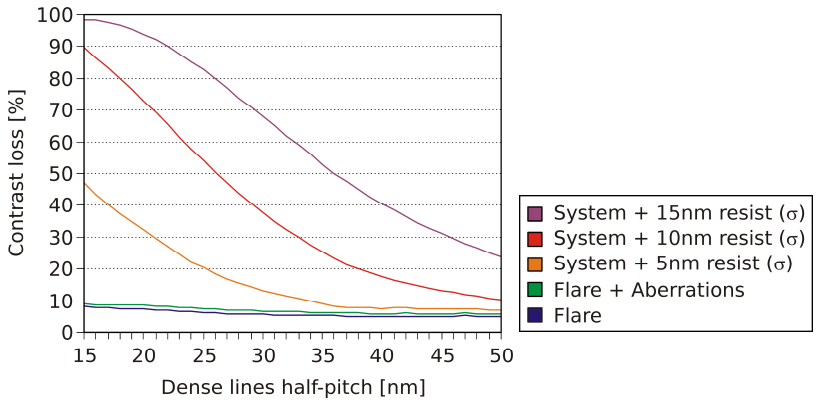
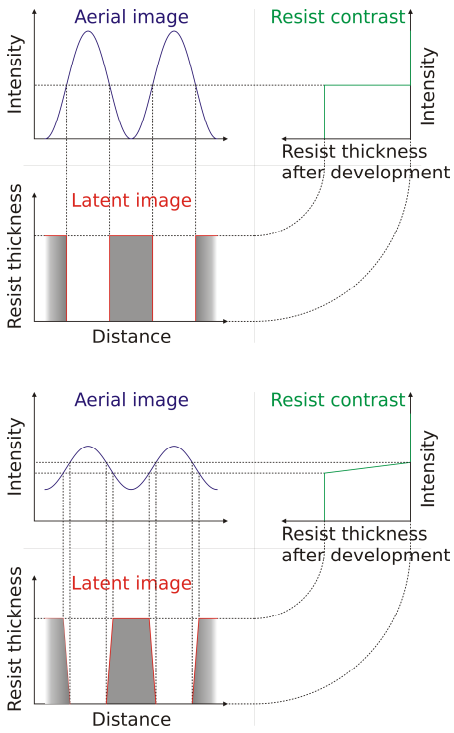
Motivation & Introduction

- Resist-induced contrast loss is becoming increasingly important for smaller pitches
- Current resists have ~10nm sigma blur, whereas EUV targets 22-27nm to start with ⇨ Resist consumes >50% of the contrast budget and dominates imaging:

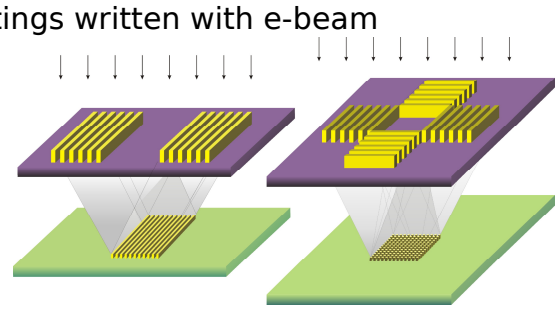


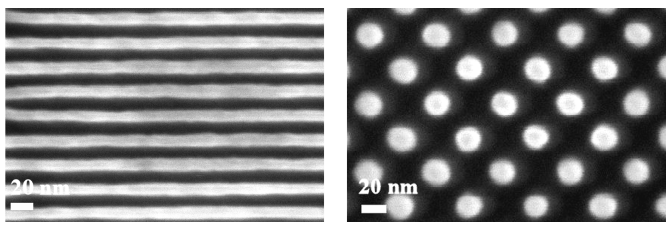
- EUV-IL: can be used to determine resist contrast loss independently from the exposure tool performance



EUV-IL Setup

- Light source: undulator (synchrotron)
- Coherent illumination with 13.5nm wavelength
- Patterns obtained by interference of gratings
- Gratings written with e-beam

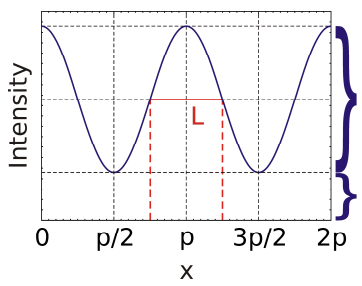




11nm lines and 19nm dots exposed in HSQ [3]

Normalized Image Log-Slope (NILS)

- Aerial image of an interference-based exposure tool:



$$I(x) = A\left(\frac{\cos(kx)+1}{2}\right) + B$$

A(mplitude)

B(ackground)

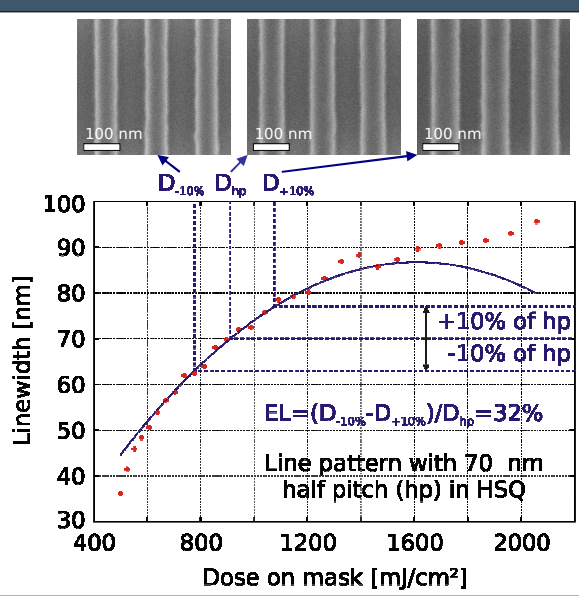
- A measure for image contrast is NILS:

$$NILS = L\frac{\partial \ln I}{\partial x} = \frac{A}{A+2B}\pi = \mu\pi$$

- NILS is pitch-independent in interference lithography

Exposure Latitude (EL)

- EL = percent change in dose for ±10% change in linewidth (LW)
- Ideal interference lithography experiment: EL = 10·NILS = 10π
  - ⇨ No resist contrast loss
  - ⇨ Zero background (B = 0)
- Ratio of EL to 10·NILS provides a direct measure of how well the aerial image is transferred into the resist:
  - ⇨ EL/(10·NILS) = 1: resist image fully determined by aerial image, i.e. no resist contrast loss
  - ⇨ EL/(10·NILS) < 1: resist causes contrast loss

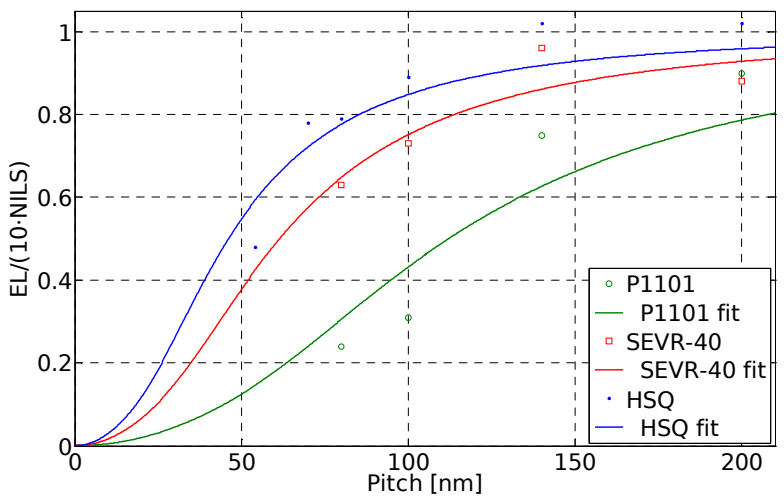


Preliminary Results

- For EL measurements EUV resists were exposed with several pitches in the range of 50 to 200nm
- SEM top down analysis of latent resist images
- LW characterization using software-based characterization tool [4]
- EL over pitch data fitted with Modulation Transfer Function (MTF) via acid diffusion length (L_D) [5]

Tested Resist	Tone	CA	L_D* [nm]	EL / (10·NILS) at 27nm hp	EL / (10·NILS) > 0.6 at hp	R^2 of fit
Fujifilm FEVS-P1101	positive	yes	32	0.145	67nm	0.85
Shin-Etsu SEVR-40	positive	yes	17	0.423	37nm	0.80
HSQ	negative	no	13	0.592	28nm	0.84

*preliminary values, further work necessary



$$MTF_{diff} = \frac{1-\exp\left[-2\pi^2\left(L_D/p\right)^2\right]}{2\pi^2\left(L_D/p\right)^2}$$

Background

- Caused by mask roughness or higher diffraction orders
- Estimated to be in the range of a few percent
- Lowers the tool contrast as characterized by NILS (see table below)
- Example: accumulated background of 5% decreases tool contrast by 10%

Background	NILS value
0%	1.00π
5%	0.90π
10%	0.82π
15%	0.74π
20%	0.67π

Conclusions & Outlook

- Alternative method based on interference lithography established for EUV resist contrast loss characterization
- For target hp 27nm resist contrast loss of the tested resists seems to be too high
- Further work is necessary to give a more precise number for the tool contrast

Acknowledgement: Markus Kropf, Helena Pruchova, Anja Weber, Bianca Haas, Sarkar Sankha Subhra

References

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[5] D. van Steenwinckel et al., J. Micro/Nanolith. MEMS MOEMS 7, 023002 (2008).